SYSTEM AND METHOD FOR NON-CONTACT WEAR MEASUREMENT OF DICING SAW BLADES

FIELD OF THE INVENTION

This invention relates generally to the dicing of semiconductor wafers, substrates and hard materials. More specifically, the present invention relates to a system and method to monitor and measure the wear of dicing saw blades used to dice hard material substrates.

BACKGROUND OF THE INVENTION

Die separation, or dicing, by sawing is the process of cutting a substrate into its individual circuit die with a rotating circular abrasive saw blade. This process has proven to be the most efficient and economical method in use today. It provides versatility in selection of depth and width (kerf) of cut, as well as selection of surface finish, and can be used to saw either partially or completely through a wafer or substrate.

FIG. 1 is an isometric view of a semiconductor wafer 100 during the fabrication of semiconductor devices. A conventional semiconductor wafer 100 may have a plurality of chips, or dies, 100a, 100b, . . . formed on its top surface. In order to separate the chips 100a, 100b, . . . from one another and the wafer 100, a series of orthogonal lines or "streets" 102, 104 are cut into the wafer 100. This process is also known as dicing the wafer.

Dicing saw blades are made in the form of an annular disc that is either clamped between the flanges of a hub or built on a hub that accurately positions the thin flexible saw blade. The blade is rotated by an integrated spindle-motor to cut into the workpiece.

Wafer dicing technology has progressed rapidly, and dicing is now a mandatory procedure in most front-end semiconductor packaging operations. It is used extensively for separation of die on silicon integrated circuit wafers.

Increasing use of microelectronic technology in microwave and hybrid circuits, memories, computers, defense and medical electronics has created an array of new and difficult problems for the industry. More expensive and exotic materials, such as sapphire, garnet, alumina, ceramic, glass, quartz, ferrite, piezo-electric materials (PZT), alumina (Al_2O_3) and other hard, brittle substrates, are being used mainly due to the exploding markets in optical communication components and telecommunications. In addition to these relatively new markets, the traditional markets for hard materials, such as, sensors, automotive components, ceramic ball grid array (CGBA), capacitors, and PZT based surface acoustic wave filters and ultrasound transducers are all exhibiting high growth rates in recent years.

Dicing hard materials is a challenge for the dicing industry. In order to maintain high dicing quality, namely, low top and backside chipping, along with reasonable throughput, the use or resinoid blades is desirable. A resinoid blade has a soft resin based matrix acting as a binder of the diamond particles which, in turn, perform the abrasive dicing process.

Relative to nickel binder type blades, predominately used in the dicing process of integrated circuits, resinoid blades have a blade wear rate that is larger than that of nickel binder type blades by at least an order of magnitude. Although blade wear is application dependent, an example may be useful to illustrate this point. For a resinoid blade used in dicing a glass type substrate, the blade wear is about five micron/meter of dicing length. By contrast, for a nickel binder type blade, used in dicing silicon IC wafers the blade wear is about 0.1 micron (or less) per meter of dicing length.

Conventional methods of monitoring dicing saw blade wear are time consuming. As such, where high blade wear exists processing throughput is significantly reduced. In one such conventional contact method, a blade wear station, based on measuring the height of the blade, is incorporated in the dicing area of the machine. To accomplish this method 1) the height station and the blade tip are brought on top of each other (height station below saw blade tip) through motion in the X-Y plane; 2) the blade is gradually lowered along the z-axis into the height station; 3) the blade tip is brought into contact with the height station sensor to determine the amount of wear of the blade; and 4) the height station and blade are

separated from one another and dicing continues. This method is illustrated in U.S. Patent 5,718,615 to Boucher et al.

In another conventional non-contact method, Step 3) above is modified such that the side of the blade interrupts the path of a light source projected between two prisms to determine the height of the blade and thereby the position of the end of the blade. This method is illustrated in U.S. Patents 5,353,551 and 5,433,649 to Nishida.

The prior art is deficient, however, in that the conventional methods are time consuming since the blade and height monitoring station must be moved in X, Y and Z directions relative to one another to begin the height measuring process and then separated from one another after the blade wear is determined. It is estimated that this process lasts a minimum of 15 seconds, thereby significantly impacting device throughput, particularly in applications where large blade wear is present.

There is a need to monitor blade wear during wafer or substrate dicing for optimizing the dicing process and maintaining a high cut quality so as not to damage the substrate, often containing electronic chips or optoelectronic devices valued in the many thousands of dollars. There is also a need to perform fast monitoring so as to reduce cost of ownership.

SUMMARY OF THE INVENTION

In view of the shortcomings of the prior art, it is an object of the present invention to help optimize the monitoring of dicing saw blade wear.

The present invention is a device for monitoring dicing saw blade wear. The device has a light source to emit light onto an end surface of the saw blade; a sensor for receiving a reflection of a portion of the light from the end surface of the saw blade; and a processor coupled to the sensor for determining wear of the saw blade based on an output from the sensor.

According to another aspect of the invention, the sensor is a plurality of sensors.

According to a further aspect of the invention, the monitoring device is mounted on a cooling block of the saw blade.

According to still another aspect of the invention, a position sensitive detector is used to sense the wear of the saw blade.

According to yet another aspect of the present invention, predicted wear of the blade is determined and communicated to the operator and/or control center.

According to a further aspect of the invention, the wear rate of the saw blade and/or an estimated time for replacement of the saw blade may be communicated to the operator or control center.

These and other aspects of the invention are set forth below with reference to the drawings and the description of exemplary embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is best understood from the following detailed description when read in connection with the accompanying drawing. It is emphasized that, according to common practice, the various features of the drawing are not to scale. On the contrary, the dimensions of the various features are arbitrarily expanded or reduced for clarity. Included in the drawing are the following Figures:

Fig. 1 is an isometric view of a semiconductor wafer used to form semiconductor devices;

Fig. 2 is a perspective view of an exemplary embodiment of the present invention;

Fig. 3A is a diagram showing the blade wear monitoring principle according to a first exemplary embodiment of Fig. 2;

Fig. 3B is a diagram showing the blade wear monitoring principle according to a second exemplary embodiment of Fig. 2;

Fig. 4 is a flow chart illustrating a method for monitoring saw blade wear according to an exemplary embodiment of the present invention;

Fig. 5 is a diagram illustrating the details relating to determining saw blade wear according to an exemplary embodiment of the present invention; and

Fig. 6 is block diagram of a system according to an exemplary embodiment of the present invention.

DETAILED DESCRIPTION

Referring to Fig. 2, an exemplary embodiment of the present invention is shown. In Fig. 2, a portion of a dicing machine is shown in which saw blade 220 is used to cut a workpiece (not shown in this figure). Adjacent saw blade 220 is blade housing 210 which also functions as a cooling block. Mounted above cooling block 210 is wear measuring device 200. As shown in Fig. 2, wear measuring device 200 is fixedly disposed above saw blade 220. In the exemplary embodiment, it is not necessary for blade 220 and wear measuring device 200 to be moved relative to one another in order to determine the wear of saw blade 200. As such, the time required to perform this important step during the dicing process is significantly reduced over that of the prior art, thereby increasing process throughput.

Fig. 3A illustrates the details of the blade wear monitoring system according to a first exemplary embodiment of the present invention. In Fig. 3A, light source 300 emits light 301 passing through optical elements 302 as focused light spot 303 onto an end surface 222 (blade tip) of saw blade 220. In the embodiment, light source 300, such as a diode laser, emits light in either the red and near infrared region of the spectrum, such as between 600 and 800 nm, and preferably about 780 nm. The invention is not so limited in that the wavelength of light may be selected based on the type of sensors used.

As shown in Fig. 3A, detector 308 receives, at some angle, through optic elements 306, reflections 304 of a portion of light 301 from end surface 222 of the saw blade 220. In a preferred embodiment, the angle at which light is received by detector 308 is about 43 degrees. The light spot focused on detector 308 is an image of the light spot 303 projected from the light source 300 onto blade tip 222. A certain amount of light 310 will be scattered from blade tip 222 and not received by sensor 308. In one embodiment of the present invention, wear measuring device 200, is a laser distance sensor Model LDS manufactured by Laser Measurements International

of Delta, British Columbia, Canada, whereas sensor 308 is a position sensitive detector (PSD). In other embodiment, detector 308 may be a CCD device.

Since a change in the distance of the measured object from light source 300 is reflected through a change of the image spot position at the detector surface, the output electrical signal of sensor 308 is therefore correlated to the position of the object that the detected light was reflected from. In this case, the position of end surface 222 of saw blade 220 from light source 300. This measurement method is known as triangulation.

Fig. 3B illustrates the details of a second exemplary embodiment of the present invention. In this embodiment, a plurality of sensors 308, 309 receive, through optic elements 306, 307, reflections 304, 305, respectively, of a portion of light 301 from end surface 222 of the saw blade 220. The use of multiple sensors will increase the accuracy of the system over the single sensor system described above, nevertheless the triangulation method described above is used in both embodiments. A certain amount of light 310 will be scattered from end surface 310 and not received by sensors 308, 309. As in the first embodiment, sensors 308, 309 are either position sensitive detectors (PSD) or CCD devices. The electrical signal output by sensors 308, 309 are correlated to the position of the object that the detected light was reflected from. In this case, the position of blade tip 222 of saw blade 220 relative to the light source 300.

In the exemplary embodiments the output voltage of sensors 308, 309 is linearly related to the distance from the light source 300 to end surface 222 of blade 220. To translate the change in voltage output by sensors 308, 309 to a corresponding distance variation, a calibration factor is applied. This calibration factor is based on the specific design of the sensor and is thus supplied by the manufacturer of the sensor. In the exemplary embodiment, using a laser twin sensor such as a Model LTS 15/3 manufactured by Laser Measurements International of Delta, British Columbia, Canada, the calibration factor is 5 mV per 1 micron.

In the exemplary embodiment of Fig. 3B, it is contemplated that the measurement range 312 of wear measuring device 200 is about 2.9 microns. As shown in Figs. 3A and 3B, wear measuring device 200 is disposed above saw blade 220 such that the stand-off distance 316 between wear measuring device 200 and saw

blade 220 is about 15 mm. As a result, offset distance 314 is about 13.7 mm based on Eq. 1:

Eq. 1 $$OD = SO - MR/2$$

where, OD = offset distance 314;
SO = standoff distance 316;
MR = measurement range 312.

These ranges may vary, however, based on the specifications of the sensor model.

A processor 604 (shown in Fig. 6) is coupled to each of sensors 308, 309 for determining wear of saw blade 220 based on the correlated output from sensors 308, 309.

The response of the PSD/CCD device enables monitoring of the blade wear relative to an initial blade position. This is illustrated in Fig. 5, in which light ray 303 from light source 300 is directed on the end of saw blade 220. As shown in Fig. 5, which illustrates a single sensor system for simplicity, initially, when saw blade 220 is new for example, light 303 is reflected from edge 502 of saw blade 220 as reflected light 506 to position 508 on sensor 308. Sensor 308, in response to receiving these reflected light beams, produces an output signal based upon the position of the reflected light beam on the surface of sensor 308. In the case of a new blade this value may be stored in a memory, for example, in order to have a baseline for comparison.

Subsequently, after dicing portion of the workpiece, saw blade 220 is once again measured to determine blade wear. In this case, assuming that saw blade 220 has become worn, edge 504 represents the end of the saw blade. As a result, light 303 is reflected as reflected rays 510, and received by sensor 308 at position 512. Once again, sensor 308 outputs a signal indicative of the position of the reflected light beam upon sensor 308. This output signal is compared with the initial signal (representing a new blade) to determine blade wear.

Of course, in the event the blade exposure has not reached a minimum value, dicing operations may continue. If, on the other hand, the blade exposure

meets or exceeds the minimum blade exposure requirements, the operator may be alerted to replace the blade with a new one, or to replace a flange with a smaller outer diameter in order to prevent damage to further processed substrates.

Fig. 6 is a block diagram of an exemplary processing system according to the present invention. In Fig. 6, sensors 308, 309 are coupled to converter 604 to convert the analog outputs 600, 602 of sensors 308, 309, respectively, into digital signals. These digital signals are in turn input into processor 606 for processing. Of course, in the event that sensors provide a digital output signal, converter 604 may be eliminated. Processor 606 determines in real time the blade wear based on the information received from sensors 308, 309 and the initial values stored in memory 608. Memory 608 may be any convention memory storage device or medium. It is also contemplated that the operator may enter the initial values into the system though conventional input devices such as a keyboard, mouse, network connection, or wireless means.

Referring again to Fig. 6, processor 606 may also be coupled to a display device 610 to display the results of the calculation, such as the present wear of the saw blade and wear rate, and provide guidance to the operator if the saw blade needs replacement. It is also contemplated that the processor may determine potential saw blade failure or life expectancy, based on historic information maintained in memory 608 when compared to measurement data for the saw blade. Likewise, this life expectancy may be displayed on display 610 and periodically updated by processor 606. Moreover, in terms of process control, a drastic change in saw blade wear indicates process failure, for example blade breakage.

Fig. 4 is a flow chart illustrating the method of monitoring saw blade wear according to an exemplary embodiment of the present invention. At Step 400, light is emitted onto the cutting edge of the saw blade. At Step 405, sensors receive a reflection of a portion of the light from the edge of the saw blade. At Step 410, the distance between the sensor and the saw blade is measured based on the position of the reflected light on the sensor surface. At Step 415, the wear of the saw blade is determined based on a comparison of the current and the previously measured distances between the saw blade tip and the light source.

Although the invention has been described with reference to exemplary embodiments, it is not limited thereto. Rather, the appended claims should be construed to include other variants and embodiments of the invention which may be made by those skilled in the art without departing from the true spirit and scope of the present invention.